F. M. Kenworthy

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Note.—A paper, entitled "The Capacities and 'Capacity Equations' of some West Australian Dam Sites." was read on 19th April, 1920, by A. J. Hillman (Member) and published in the 1st Volume of the Proceedings of the Institution of Engineers, Australia.

WATER SUPPLY TO AN ARMY CORPS ON THE WESTERN FRONT.

By F. W. Lawson, Member.

Read 14th June, 1920.

I do not propose to-night to enter into anything in the way of description of military operations, but intend to try and confine the paper to the Civil Engineers' view of military work which might be reasonably classed as within the scope of any Civil Engineer, especially one trained in hydraulic work. I must, however, give a few figures as to what can be taken as the fighting strength of the Australian Corps during the major operations in the Western Front, say, for instance, for the period after the taking of Villers-Bretonneux, and the advance on and after the 8th August, 1918. An Army Corps such as the Australian Corps consisted of five Divisions, each Division having a fighting strength of about 20,000 men. Attached to the Corps were a number of troops, such as heavy artillery, army troops, siege batteries, and others, which amounted to a further 10,000 men. In addition to these, there was the motor transport service, which fluctuated from day to day. Very seldom did the number of horses on our Corps Front fall below 80,000. It will therefore be seen that to supply water to such a large number of men and horses—when it is considered that the troops were changing their position almost daily, not only advancing, but continuously moving in and out of the line as the various divisions were relieved after their term in the trenches and going back to the country behind the fighting area for a period of rest and reorganisation—was no light task.

The Corps Front, that is, the fighting front, varied in length. Sometimes as much as five miles would be held by the Australian Corps, and then perhaps the Corps would

be closed in till the frontage probably was just about two miles, or under. In depth, however, the variation was very great, and at times the depth would be forty miles. Indeed, at one period of the Corps' existence we held and operated practically the whole of the Army Area.

The system of supply of stores for water supply and other engineering works was simplicity itself. The British War Authorities obtained all the stock that could be got hold of, and this was shipped across to the Base Depots of France, and distributed by General Headquarters to various armies in a ratio which was worked out on their probable requirements. For instance, the Army that was advancing would have a more liberal allowance than an army that was sitting down in occupation of certain areas. The Army asked the various Corps working under the army to forecast their requirements generally, say, for a period of three months. The Chief Engineer of the Army would make the allotments in accordance with the requirements of each individual corps, taking into consideration their capacity for work and the possibility of their being engaged in offensive operations. Stores were then drawn from the Army as required to the amount of the allotment and taken to the Corps Depots, where they would be placed under the control of an Engineer Officer on the Staff of the Chief Engineer for the Corps. The Officer-in-Charge of Water Supply work would be responsible for drawing these stores as he wanted them and for having them transported to the various sites where work was to be in progress.

Needless to say, of course, the best arrangements had to be made to keep a certain amount of stores in hand, for the reason that very often the enemy would take a particular interest in some water supply work and the water supply stores would be very much damaged and put out of use. This can be readily understood, as a newly-dug pipe line would be very plainly marked on an enemy air photograph, and this, of course, would bring the usual straafe along this particular line, especially if it happened to be fairly close to the Front line.

The method of obtaining labour was as follows:—Attached to every Corps would be a certain number of Engineer Companies, and amongst these would be an Army

Troops Company, or, perhaps, if occasion warranted it, two Army Troops Companies, which consisted of four officers and one hundred skilled sappers, especially trained in water supply work. These men in civil life were men employed on water supply work, or plumbers, or engineers. In addition to these, Field Companies—and I might say that the Australian Field Companies proved particularly adaptable and capable for this kind of work—were always available, and a word of praise is also due to the Australian Pioneer for his aptitude for doing what was asked of him.

Unskilled labour for trench digging was provided mainly from infantry battalions in rest, and requisitions for working parties were made in accordance with the magnitude of the work. Where their services could be utilised in the back areas Chinese Labour Companies and English Labour Companies were also used. The Chinaman proved a particularly good workman outside of the shelled areas. Of course, in the battle zone the work had to be done by the fighting troops. To give some idea of how much work was progressing at the one time, there have been as many as 1200 troops employed on excavation work, two Army Troops Companies, an Australian Field Company, and a Company of Pioneers all employed on water supply work. The average amount of excavation that could be depended on was ten lineal yards of trench, two feet wide and two feet six inches deep, per diem for each man, and the work was generally set out on this basis as a task.

The whole of the country that was being fought over in France was country that had been very closely settled for hundreds of years, hardly any of the land not being in cultivation, and the so-called forests being woods where every tree was particularly trained and cared for.

It can be seen that there was no possibility, except in very rare instances where springs were met with, of obtaining water from unpolluted sources, and later on I will endeavour to describe the various methods by which water was treated and rendered fit for drinking purposes. It might be just as well to mention at this point, however, that in spite of all the pollution, not only from the cultivation, but also from the number of troops, horses, etc., in

the Corps Area, the system of purification had been so thoroughly worked out that it was very rare indeed to find a case of typhoid or enteric fever amongst the troops that could be traced in any way to the water supplied, showing, therefore, that these methods were satisfactory and preserved the health of a number of men who would otherwise have suffered from untold hardships likely to ruin their physical condition and rendering them easy prey to diseases such as those mentioned.

SOURCES OF SUPPLY.

The sources of supply were many and varied. Sometimes, but very occasionally, a spring would be found coming from under a chalk hill, and of course this would be utilised wherever possible. In some cases the supply was obtained from an old communal well that had been put down for the village supply. Another source of supply were the wells in the large factories, such as butter or beet sugar factories, etc., and some of the large flax and woollen mills.

As we approached the artesian basin, bores also would be sunk, these bores going down to 350ft. in depth, and 6in. in diameter, but in no case were we successful in getting a proper artesian bore, the bores always proving sub-artesian, and the water being lifted by means of compressed air or a deep well pump of the types which will be described later.

Where time would permit, wells were sunk and pumping machinery installed. In the fighting area, wherever it could be done, the pumping plant was put well below ground so as to provide protection from shell fire.

Practically every running stream was utilised as a source of supply of drinking water for the troops. That is, after purification, and a running stream, of course, was looked upon as a special gift from the gods for the supply to horses.

In addition, a good many of the larger so-called lakes were used for obtaining water, such, for instance, as Dicke

Busch Lake and the Zillebeke Lake, and these proved of great service. It is interesting to mention that both these lakes were used in pre-war times as a source of supply to the city of Ypres, and during the time that the writer was in this locality a portion of the old works still remained.

METHOD OF SUPPLY.

Pumps.—The type of pump used in France varied considerably, and practically all types were used, from the steam driven pumps, such as the Worthington Horizontal, down to the ordinary cottage pump; but, in addition to these, there were two special types of pump to which I would direct your attention, namely, the French pump known as the Chaine-Helice, and a type of Band pump evolved by the Army after considerable experiment. A brief description of the Chaine-Helice Pump might not be out of place, as this is a type of pump that could be very well adopted throughout Australia for ordinary wells, and experience shows that it is the most reliable pump as well as being the most simple. The principle consists of an endless chain round which is wound spiral wires forming practically a system of endless buckets which lift the water by capillary attraction from the bottom of the well to the pump head. The chain revolves over a grooved wheel, and, when travelling at the right speed, throws the water clear of the chain. There are several important points to be watched in operating Chaine-Helice Pumps. These are set out in the following Army Circular:—

INSTRUCTIONS REGARDING THE USE OF THE CHAINE-HELICE PUMPS.

Chain Crossed.—Must absolutely be avoided.

Stop the pump immediately if this should happen, and bring back to right position.

Immersion of Balance Pulley.—The pulley must be totally immersed. Stop immediately if the water level falls below the pulley. This is brought to your notice by a fall in the yield.

An immersion of 1 metre is excellent. One can go so much deeper without danger.

The pulley must never touch the sides.

Verify periodically the depth below the balance pulley, as it becomes smaller as the chain lengthens.

If necessary shorten the chain.

A very precise way of verifying the length of the chain is to count the number of revolutions of the handle for one complete rotation of the chain.

Neglect of ese precaut-ns render a eak in con-uity of the ing water lumn and ry consider-ly reduces e efficiency the pump.

Spiral Thread.—Verify that the windings are uniform.

If the spirals get too loose, especially near the point where they are joined together, the threads are subject to a greater strain when they pass over the pulley, and therefore get worn out and break.

This will be obviated by frequent inspections (at least once a week, every three days, or even every day if necessary) of the chain, which will be slowly pulled along by hand.

If an abnormal space is noticed between the spirals, they will have to be brought together again by means of pliers or a punch.

If the threads should break, repair immediately, taking care that the inner chain remains completely covered.

If necessary, cut the inner chain, shorten it and join up with a new link.

Before doing this, one must try to bring the spirals to a uniform spacing on about 2 metres of the chain formed by one of the spiral threads.

Anchoring of the Chain.—When it is necessary to keep the chain from moving, or when the pump is being put up, never hold the chain by the spiral thread. Anchor the inner chain or hold that chain.

When repairing the spiral thread, do not allow the chain to turn around its axis, as one would thus bring about the crossing of the chain as told in para. 1.

After each repair, start slowly and see that the two parts of the chain remain vertical.

Engine.—Must work regularly. The normal speed is 200 to 240 revolutions per minute.

Be careful not to let the belt slide, nor to have bursts of speed or any jolts which would more or less empty the chain.

Lubricating.—Verify lubrication of bearings. Avoid all heating of bearings.

Inscribe on a book the hours of work, quantity of petrol used, oil used, incidents, accidents, repairs.

A hand-driven pump would supply up to 600 gallons per hour, while a pump driven by a small Petters Junior petrol engine of 3 h.p. would give 1200 gallons per hour from a well 120 feet deep. One of the good features about this type of pump is that it can be fixed at any height above the coping of the well and will deliver water into water carts or horse troughs without any auxiliary lift.

The type of Band Pump described hereunder gives the quantity of water as set out in the attached table.

The following conclusions have been drawn from experiments carried out with this pump in wells of varying depths :—

The diameter of belt drum was 1ft. 3ins., and it had a camber of 1/24:

The belt used was 8ins. wide and weighed .346lbs. per yard run.

(a) *Slip* is best guarded against by tacking a strip of canvas 4ins. wide round the middle of the pulley:

(b) *Immersion.*—The best results are obtained with a belt of such a length that its lowest point is

six inches from the bottom of the well when the pump is not working:

(c) *Depth from Ground to Water.*—As the depth from ground to water decreases, the belt has less chance of becoming steady before reaching the drum; also, there is less weight on the drum and more tendency to slip, and therefore more tendency for the belt to wear. This is overcome by using two or more belts superimposed.

With wells 200ft. — 100ft. use a single belt.

Do. 100ft. — 50ft. use two belts superimposed.

Do. 50ft. — 30ft. use three belts superimposed.

Superimposed belts should be tacked together every five feet.

(d) Generally speaking, the deeper the well the greater may the speed be. If the speed is too great for any particular depth of well, the belt will "hunt" from side of the drum, and rapid wear will result owing to the edges of the belt running against the sides of the notches.

The following table shows the maximum output and belt speed for wells of various depths, the bottom of the belt being, in each case, ten feet under water when the pump is not working. Below these speeds, the output will be in direct proportion to the speeds.

In Column "X" the maximum quantity of water that can be obtained with this pump and a 5-h.p. Petter Junior engine is shown; but if these deliveries are required, the belt will wear out very quickly.

(e) No form of bottom pulley has been found to give satisfactory results.

Table showing the Maximum Output and Belt Speed for wells of various depths.

Depth from pump drum to water.	Total length of belting under water	Belt speed	Output g.p.h.	Belt used	Maximum delivery obtainable "X"	Belt speed	Remarks
197 feet	20 feet	1600	2000	Single			
		1330	1500*				
155 feet	20 feet	1320	2000	Single	2400	1520	Limit of power of 5 h.p. Petter Engine.
155 feet	20 feet	1120	1500*				
110 feet	20 feet	1120	2000	Single	2700	1400	Belt slips after this speed.
110 feet	20 feet	920	1500*	Single			
66 feet	20 feet	960	2000	Double			
43 feet	20 feet	800	2000		3200	1620	Belt slips after this speed and output goes down.
		640	1700				

* Best Speed

The output diagrams are worthy of close study. The only objection to this type of pump is that great care must be exercised in getting good tough hessian for a belt, and experience shows that this hessian should be at least two-ply.

Another type of machine used for lifting water was the movable air-compressing pumping plant. This machine was used for lifting water from the sub-artesian bores, and under favourable conditions would yield up to 6000 gallons per hour, if the well was capable of giving that quantity of water. This plant was fitted on an ordinary three-ton lorry, and during the offensive operations one lorry would serve four distinct water points, visiting each in turn and filling the storage tanks. The lorries used were mostly of British manufacture, and stood the vibration of the machinery very well. The engine was a 30-h.p. petrol-driven engine, manufactured by Astor Webley, with four cylinders 150 m.m. bore, and 130 m.m. stroke, the speed being 1000 revolutions per minute. The compressors used were manufactured by Broome and Wade and were capable of supplying 145 c. feet of free air per minute at a pressure of 100lbs. per square inch, having two cylinders each 7in. bore and 8in. stroke, single acting, the speed being 450 revolutions per minute. This plant was very compact and gave excellent service.

TREATMENT OF WATER FOR STERILIZATION.

There were several methods of treatment used, namely:

(a) *Removal of Suspended Matter*:—

The removal of suspended matter from water was not in itself sufficient to render it fit for consumption.

Conversely, removal of suspended matter was not always a necessary factor in the successful production of safe water. It was extremely desirable, however, that the suspended matter should be removed, since a clear palatable water was more likely to be drunk than one which, although safe, was not to be distinguished in appearance from untreated water.

By the removal of suspended matter further anti-bacterial treatment was to some extent facilitated, and the removal of their food matter was a deterrent to the propagation of fresh bacteria.

(1) *Precipitation of the Suspended Matter by Means of a Coagulant*:—

For this process several coagulants were in use, of which alumino-ferric was the commonest and most efficient.

On adding a solution of alumino-ferric to the water a flocculent precipitate of aluminium hydroxide was formed, which falling gradually to the bottom of the settling tank carried with it the suspended matter.

For the proper formation of the precipitate the water had to give no acidic reaction—hence it may be necessary to add a proportion of a basic compound to the water under treatment. The substance most readily employed was lime.

In practice it was found to be essential to run the water and alum solution together into the settling tank in order to ensure thorough mixing. It was an advantage, and for successful sedimentation frequently necessary that the water be kept in continued circulation during the filling of the tank. This was arranged by placing the pipe leading from the alum solution tank above the crude water inflow and running the mixed water along a slightly sloping trough which directed the flow along one side of the tank.

After sedimentation, which sometimes took up to eight hours, the clear water was siphoned or pumped into a second tank and chlorinated when ready for use.

This method presented great advantages, especially when used on a small scale, since the plant was comparatively inexpensive, was easily erected and maintained, and few waters were so contaminated that they could not be treated in this way.

Control by qualified personnel was absolutely necessary, since the variable character of water modified the treatment required.

(2) *Filtration Through Sand or Similar Material*:—

This was at most times carried out by pressure due to a head of water or pressure produced by mechanical means.

The slow descent sand filter beds of peace time waterworks were not always suitable for Active Service conditions on account of the labour required for their construc-

tion and maintenance when working, and their inability to deal with a heavily charged water.

Mechanical filters in which a layer of sand of small superficial area was used as a support for a film formed by a suitable coagulant such as alumino-ferric, were better suited for war conditions. Those plants, however, of capacities of and above 6000 gallons per hour, entailed a large amount of skilled labour in their erection, required stable foundations, and were not easily moved.

(b) *Anti-Bacterial Treatment*:—

The agent commonly used for disposal of harmful bacteria is chlorine, which was introduced either in the form of calcium hypochlorite (bleaching powder) or as a gas. The unit of measure in use in the Army for the addition of bleaching powder was a "Scoop," which, if added to 110 gallons of water, was equivalent to an addition of one part of "free" chlorine to 1,000,000 parts of water.

The addition of over two scoops was liable to render the water unpleasant to the taste. This was often due to excess of chlorine, resulting from the fact that the amount of hypochlorite necessary was over-estimated in the first instance. Furthermore, successive samples of bleaching powder often varied quite appreciably in their "free" chlorine content.

The foregoing facts rendered the determination of the exact amount of bleach to be added a difficult matter, especially when the character of the water varied from time to time. It was the practice, however, to leave an excess in the water to take care of any unforeseen increased bacteriological impurities. It sometimes happened, however, from one of the causes enumerated before, that this excess was increased beyond the limit at which the water ceased to be palatable.

It is now generally recognised that chlorination at the initial source of supply is the scientific and most practicable method of safeguarding supplies, and that, at any rate in the case of large installations, the hypochlorite method is crude and unsatisfactory.

There has lately been brought to perfection a process by which free chlorine gas can be injected into the source of supply in any desired quantity. The apparatus consists of a sensitive and accurate meter by which the flow of

chlorine can be readjusted to within one-tenth part per 1,000,000. The chlorine is introduced by means of a diffuser, which is inserted in the flow of water to be treated. This process possesses the advantages that no substance other than free chlorine is introduced into the water, and that, being capable of such delicate regulation, the dose can be accurately administered so as to leave an excess which will not render the water unpalatable. It is evident that much heavier doses can be administered than by the hypochlorite process.

Again, since chlorine is obtained in the liquid form in cylinders, there is much saving in labour and transport, one cylinder of chlorine being roughly equivalent to 3cwt. of bleaching powder. The use of bleach tanks is unnecessary, and difficulties arising from the sparing solubility of bleaching powder are avoided.

The removal of bacteria is effected in sand filters operating with water under forced pressure, but such action is uncertain and probably non-existent when the filter is clear. In properly constructed open sand filters in which the descent of the water is slow, bacterial elimination is carried out by the action of the film which settles on the surface of the sand. The disadvantages of such plants under war conditions have already been enumerated.

The methods of purification outlined have been proved quite satisfactory, but in one or two instances, however, it was the writer's privilege to be able to instal sand filters of the slow type, and from extensive operations of these beds and from a very strict bacterial and chemical analysis there can be no doubt of the efficacy of sand filters for domestic water supply. The instances I refer to were the sand filtering plants at South Kemmel and at Scharpenburgh, where water was obtained from an area that was being intensely cultivated for beetroot and market garden purposes, and the bacterial analyses showed that the water after filtration was of good quality. I have already mentioned that a supply was obtained from Dicke Busch Lake. This lake was in the centre of a Drainage Area which was at times common to at least three Corps, and this will give some idea of the number of troops that were settled on the catchment of Dicke Busch Lake, which was some slight distance behind the actual firing line. The water from this lake was filtered through coarse sand filters and treated by means of chlorination. The following table gives the result of the bacterial and chemical analyses:—

	1	2	3
Number of Colonies growing on AGAR in 24 hours at 37 deg. C.	126	78	50
Smallest quantity of water containing the BACILLUS COLI.	10c.c.	absent in 40c.c.	absent in 75c.c.
Smallest quantity of water containing the BACILLUS ENTERITIDIS SPOROGENES	100c.c. (a)	100c.c. (a)	100c.c. (a)
Appearance	Clear, small deposit, veg. debris, life	Clear and bright	Clear and bright
Oxygen absorbed (3 hrs. at 37 deg.C.)	0.488	0.477	0.477
Free chlorine			Absent

UNTREATED WATER.

Chlorine	3.2 per 100,000.
Total hardness	21.0 ,,
Permanent hardness.. ..	8.5 ,,
Nitrates	Absent.
Nitric Nitrogen	0.025 ,,
Free Ammonia	0.008 ,,
Albuminoid Ammonia ..	0.042 ,,
Metals	Minute trace, Iron.

PIPE LINES.

The sizes of pipes used in France were limited by the difficulty in transporting large mains into the forward areas. Therefore, the largest main used was 6in., and the smallest 1½in. Unless piping could be obtained from the district, that is by utilising old water supplies to the towns, screwed and socketted pipes were invariably used, all the other devices not proving satisfactory under the severe conditions met with. The main pipes, therefore, were mainly 4in., and if this size was not ample the pipe lines were duplicated. The 1916 winter taught us that it was not safe to have piping less than 2ft. 6in. under the surface,

as, early in the winter of that year, the whole of the water supplies in the British Army were thrown into serious confusion by the freezing of many miles of piping. Afterwards, the rule was that all pipes should be laid with 2ft. 6in. of cover. The system of laying pipes was that the trenches were dug by unskilled labour and a sapper working party came along and laid the pipes. These working parties consisted of five men under a junior non-commissioned officer, who generally worked with the men, and in an ordinary shift of eight hours each gang laid 40 pipes—pipes averaging not less than 12ft. lengths.

On one occasion where it was necessary that a water supply should be put in at the shortest time possible, eight miles of pipes, two large pumps, each capable of doing 5000 gallons per hour against a 250 head, four service reservoirs each of 9000 gallon capacity, and two large water points to fill water carts, water horses and supply the troops, were completed in five days. This will give some idea of the speed at which work was carried out. This particular water system proved of very great assistance not only to the Australian Corps but to the adjoining Corps, who happened at that time to be Canadians.

METHOD OF REPAIRS TO PIPE LINES.

One of the most interesting problems that the writer found was restoring the old supply at the town of Bapaume. When the Bosche retired it was found that he had destroyed the main by use of explosives in about twenty places, had attempted to destroy the pumping station, and partially succeeded. His men had removed the headgear from the pumping machinery, but in his haste had overlooked certain spare parts which were found when we entered into occupation. The well supplying Bapaume was about 7ft. in diameter and 120ft. deep, and there were two very nice deep well pumps practically untouched at the bottom of the well just above the water level, and when the spares were found we were enabled to put the top gear of the pumps right. The engine had been destroyed by a bomb being placed in the cylinder, but a petrol-driven engine was brought up and installed and the plant was running in a few hours. The trouble then was to get the main into repair, but as it was found that this main was of sufficient diameter to allow 4in. pipes to be inserted inside the original pipe, the joints were made by caulking between the cast-iron pipe and the steel tubing put in, and a very

satisfactory arrangement was made; the water was supplied in the centre of Bapaume within quite a reasonable time.

Another interesting work was the restoration of certain of the water supplies to Villers Bretonneux. The original supply came from the Daours, the pumping plant being situated near the town of Daours, about eight miles from Villers Bretonneux. The main led up to the highest point of Villers Bretonneux, and there was a complete system of distribution in the town. This, of course, could not be restored, as it was so badly broken by shell fire, but the main was restored, as a few spare pipes were found and every expedient resorted to to put the main in working order, with the result that the original plant was used and water was sent forward to the outskirts of Villers Bretonneux just after the advance. The civilian scheme for this town was very original and worthy of a few words in passing. The pumping machinery consisted of two high-duty pumps driven from a low-pressure water turbine in the Daours River. This turbine worked under the very low head of about 15ft., and the pumps were driven from a cross head on the main shaft, the pumps being set at an angle of 45 deg. Instead of pumping direct into the main, the French have an ingenious system of pumping into a container, this container being either of cast iron or a steel cylinder, varying, of course, with the size of the plant. The water is pumped into this and gradually compresses the air in the body of the container until it becomes equal to the lift plus the friction head, and the water therefore goes direct into the main from the container without any shock or jar from the pumping plant. I was very much taken with the French method, and I found this type very frequently in the Northern portions of France.

STERILIZING LORRIES.

Where it is not possible to instal stationary sterilising plants owing to the movements of troops being very rapid, the purification of water was done by means of sterilizing lorries. These lorries contained a complete sterilizing plant, including a pressure filter and a chlorinating apparatus, and the whole of this plant was put on either a 3 or 5 ton lorry. The small plant on the 3-ton lorry was rated to give 500 gallons of pure water per hour, but in times of great demand this plant was worked up to a capacity of 800 gallons per hour. The large, or 5-ton lorry, was rated at 1200 gallons, but did, on occasions, up to 1500 gallons. They were so designed that they would

draw water from a stream and pump into tank or vehicle 12ft. above ground. These lorries gave excellent service and on many occasions proved invaluable to the troops. It became necessary, however, to always fix a storage tank of some sort in connection with the lorry, otherwise there was great congestion at the various water points. A lorry of this type would be most useful in all military camps or where there are floating populations in this State, such as the Goldfields, etc.

STORAGE OF WATER.

It was possible in some instances to erect small impounding reservoirs such as those mentioned at Kemmel and Scharpenburgh, but these of course were exceptions, and necessitated long pipe lines to give supplies, and could only be used in areas which were more or less behind the fighting zone. The usual storage reservoir was constructed of a 30ft. x 30ft. tarpaulin or sail cloth, which gave a storage of about 9000 gallons gross, or 8000 net. These were installed singly or in groups of four if necessary, to give supplies for troops and horse watering. The tarpaulins or sail cloths are always re-tarred before being put into use, and it was found that these cloths or tarpaulins lasted quite a long time when the following precautions were taken:—That all the frames were made on the small side so that the canvas hung loose in the frame without tension; that they were sand-bagged round to prevent damage from shell fire; that they were covered and fenced in to prevent damage by the troops or straying horses, and, when necessary, were camouflaged from enemy observation. The writer well remembers one case of four of these storage tanks coming under the Bosche observation, and the very same afternoon the whole installation were destroyed by shell fire from 11.8 guns. The Bosche evidently thought that this particular spot was worthy of attention.

The method of repairing any small breaks in the tarpaulins was by bringing the edges together and placing two pieces of inch board on each side of the canvas and using either a strip of rubber insertion or some freshly tarred canvas between tne boards, which were then nailed solidly together. This proved very satisfactory and lasted quite a long time.

So far I have not mentioned the quantity of water allowed. It was found that the following figures were about safe, namely, 10 gallons per horse and 1 gallon per

man during the winter, but, during the warmer weather, an increase had to be made in the quantity allowed per man to cover washing (although the Australian troops settled this difficulty by swimming in every possible source of water supply that was available, and at times the powers that be were rather angry). However, the diggers loved falling into the nearest pool, stream, or tank for that matter, if they could get there, and have a swim during any period of the year. There was no doubt that the Australian loved cleanliness, and his consumption of water for ordinary purposes was much above that of almost any of the other troops.